

Supplementary Material: gr-MRI: A software package for magnetic resonance imaging using software defined radios

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Param Name	Param Description	Units	Sequence
TR	Repetition time	s	GRE,SE,IR,FID
CF	Center frequency	Hz	GRE,SE,IR,FID
offset	Center frequency Offset	Hz	GRE,SE,IR,FID
p90	Excitation pulse length	s	GRE,SE,IR,FID
p180	Refocusing pulse length	s	SE,IR
TE	Echo time	s	GRE,SE,IR
TI	Inversion time	s	IR
BW	Readout bandwidth	Hz	GRE,SE,IR
readout_length	FID Readout length	s	FID
NRO	Matrix dimension in readout direction	integer	GRE,SE,IR
NPE	Number of phase encodes	integer	GRE,SE,IR
FOVread	Field of view, readout dimension	mm	GRE,SE,IR
FOVphase	Field of view, phase encode dimension	mm	GRE,SE,IR
readdir	Readout dimension (x=1,y=2,z=3)	integer	GRE,SE,IR
phasedir	Phase encode dimension	integer	GRE,SE,IR
slicedir	Slice dimension	integer	GRE,SE,IR
pre_dur	Readout prephasor duration	s	GRE,SE,IR
phase_dur	Phase encode gradient duration	s	GRE,SE,IR
rewinder_length	Slice gradient rewinder length	s	GRE,SE,IR
slice_thick	Slice thickness	mm	GRE,SE,IR
nav	Number of averages	integer	GRE,SE,IR,FID
TBW	Excitation pulse time-bandwidth product	unitless	GRE,SE,IR
slice_shift	Slice offset	Hz	GRE,SE,IR
ex_type	Excitation pulse shape (Square=0, Sinc=1)	integer	GRE,SE,IR
ischopped	RF Chopping (Off=0, On=1)	integer	GRE,SE,IR
interactive_mode	Pre-scan/Interactive mode (Off=0, On = 1)	integer	GRE,SE,IR
param_file	.pkl file name for automatically loaded scan parameters	string	GRE,SE,IR,FID
leader_ID	“Leader” radio serial ID (static)	string	GRE,SE,IR,FID
follower_ID	“Follower” radio serial ID (static)	string	GRE,SE,IR,FID

Table S1: Parameters that can be adjusted dynamically or in configuration files for each of the pulse sequences. All scan parameters can be changed dynamically while running the scan by calling `params.set_{param_name}({value})`, where `param_name` is the name of the parameter to be changed, and `value` is the new value to be assigned.

Function	Description	Argument
<code>params.set_{param}(value)</code>	Change value of parameter {param} and dependents	value: new value of parameter
<code>params.param_table()</code>	Display current sequence parameters	None
<code>sync()</code>	Check and adjust between-radio synchronization	None
<code>read_on()</code>	Enable readout gradient	None
<code>slice_on()</code>	Enable slice select gradient	None
<code>grads_off()</code>	Disable all gradients	None
<code>profile()</code>	Display 1D object profile with <code>params.nav</code> number of averages	None
<code>show_pulses()</code>	Plot pulse sequence	None
<code>params.save_params(file)</code>	Save scan parameters to pickle file	file: file name to save parameters to
<code>params.import_params(file)</code>	Import scan parameters from pickle file	file: file name to load parameters from
<code>calib_slice()</code>	Calibrate slice gradient rewinder	None
<code>calib_readout()</code>	Calibrate readout gradient prephaser to center signal	None
<code>run()</code>	Run imaging sequence and record data	None
<code>data.recon()</code>	Reconstruct image	None
<code>end()</code>	Stop sequence and program	None

Table S2: User interface functions defined by the three imaging pulse sequences.

Function	Description	Argument
<code>calibrate_offset(nav)</code>	Find offset from true center frequency to default center frequency	nav: number of averages
<code>calibrate_power(nav)</code>	Find the optimal excitation pulse amplitude needed to excite a 90 degree flip angle	nav: number of averages
<code>save_calib()</code>	End calibration flow graph and saves calibration data to <code>cal.pkl</code>	None

Table S3: Center frequency and power calibration functions implemented in `FID.py`.

Function	Description	Inputs
<code>sync()</code>	Check and adjust between-radio synchronization.	None
<code>grad_calib(direction)</code>	Asks for phantom size in specified dimension and calibrates the gradient strength	direction: x, y or z
<code>save_calib()</code>	End the calibration flow graph and save calibration data to <code>gcal.pkl</code>	None

Table S4: Gradient calibration functions defined by the `gradcalib.py` script.

Pulse	Radio/Channel	Input/Output	Destination
RF Excitation	Leader TX_A.A	Output	RF Amplifier
Signal recording	Leader TX_A.B	Output	Leader RX_B.B
Transmit-enable	Leader TX_B.A	Output	RF Amplifier
Leader sync	Leader TX_B.B	Output	Follower RX_B.B
RF Receive	Leader RX_A.A	Input	PC
Gx Gradient	Follower TX_B.B	Output	Gradient Amplifier
Gy Gradient	Follower TX_A.B	Output	Gradient Amplifier
Gz Gradient	Follower TX_A.A	Output	Gradient Amplifier
Follower Sync	Follower TX_B.A	Output	Follower RX_B.A

Table S5: Mapping of pulse waveforms to transmit and receive channels on the two SDRs used for the imaging experiments. The leader SDR generated and received all RF signals, and the follower SDR generated all gradient pulses. The naming convention for the channel used is *TX/RX Daughterboard_Slot A/B_Channel A/B*.

Imaging Parameter	Gradient Echo	Spin Echo	Inversion Recovery
Python script	<code>gradecho.py</code>	<code>spinecho.py</code>	<code>invrecov.py</code>
TE (ms)	1.5	10	10
TR (ms)	1000	1000	750
Flip angle (degrees)	90	90	90
Matrix size	128×128	128×128	128×128
FOV (mm ²)	20×20	20×20	20×20
Slice Thickness (mm)	4	4	5
BW (kHz)	41.7	41.7	41.7
Averages	3	3	3

Table S6: Imaging scan parameters. The inversion recovery scan was repeated eight times with TI's of 10, 25, 50, 100, 150, 200, 300, and 400 ms.

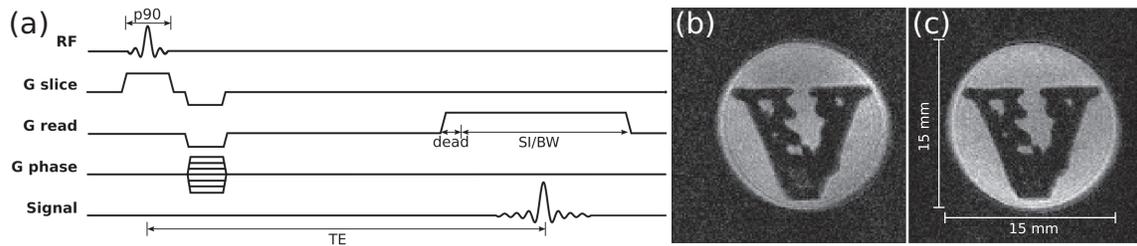


Figure S1: (a) Slice-selective gradient-recalled echo pulse sequence generated by `gradecho.py`. (b,c) Gradient-recalled echo images acquired using (b) the Maran spectrometer, and (c) gr-MRI.

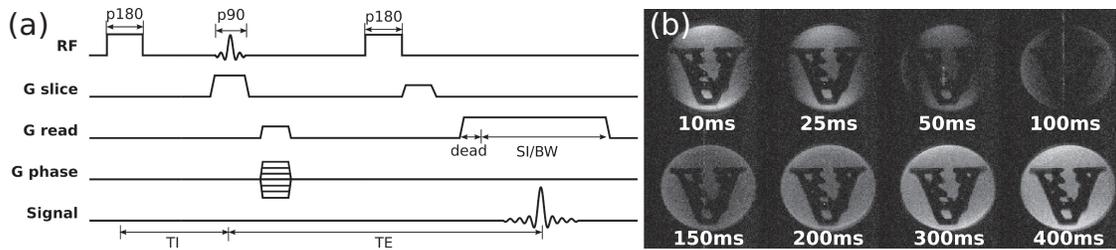


Figure S2: (a) Slice-selective inversion recovery spin echo pulse sequence generated by `invrecov.py`. (b) Images acquired using the sequence in (a) across a range of inversion times. The signal is nulled at approximately 100 ms, which is consistent with the expected oil T_1 of approximately 150 ms. Some signal intensity variations are apparent in the short-TI images due to non-uniform inversion resulting from B_1^+ inhomogeneity.